Permanent Solutions to Restore Upper Animas River Water Quality

presented to

Key Influencers On Behalf of Animas River

by

Greg Sparks, P.E.

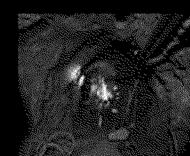
Managing Director - Metals

John T. Boyd Company

John T. Boyd Company

Mining, geological, and technical consultants

Pittsburgh - Denver - Australia – China - Colombia - India



Purpose of Presentation

Concepts for Permanent Restoration of Upper Animas Water Quality (legacy mines)

Explore Strategies to Make it a Reality

Introduction of GBS

Managing Director - Metals Group

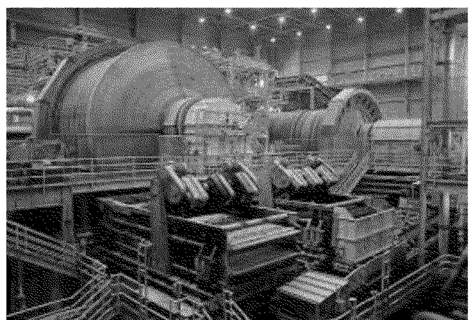
P.E. Mining Engr., Q.P., C.P. (42 years experience)

International Exposure (23 countries plus US)

Analyzed, Designed, Built, and Operated mines and plants to 50 million tpy Ore Production (s&ug)

Many years experience in Silverton District (s&ug)

Practical/Solutions Oriented



John T. Boyd Company

Technical Consultants Since 1943

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- Government Agencies
- Mining Companies
- Financial Institutions
- Legal Community

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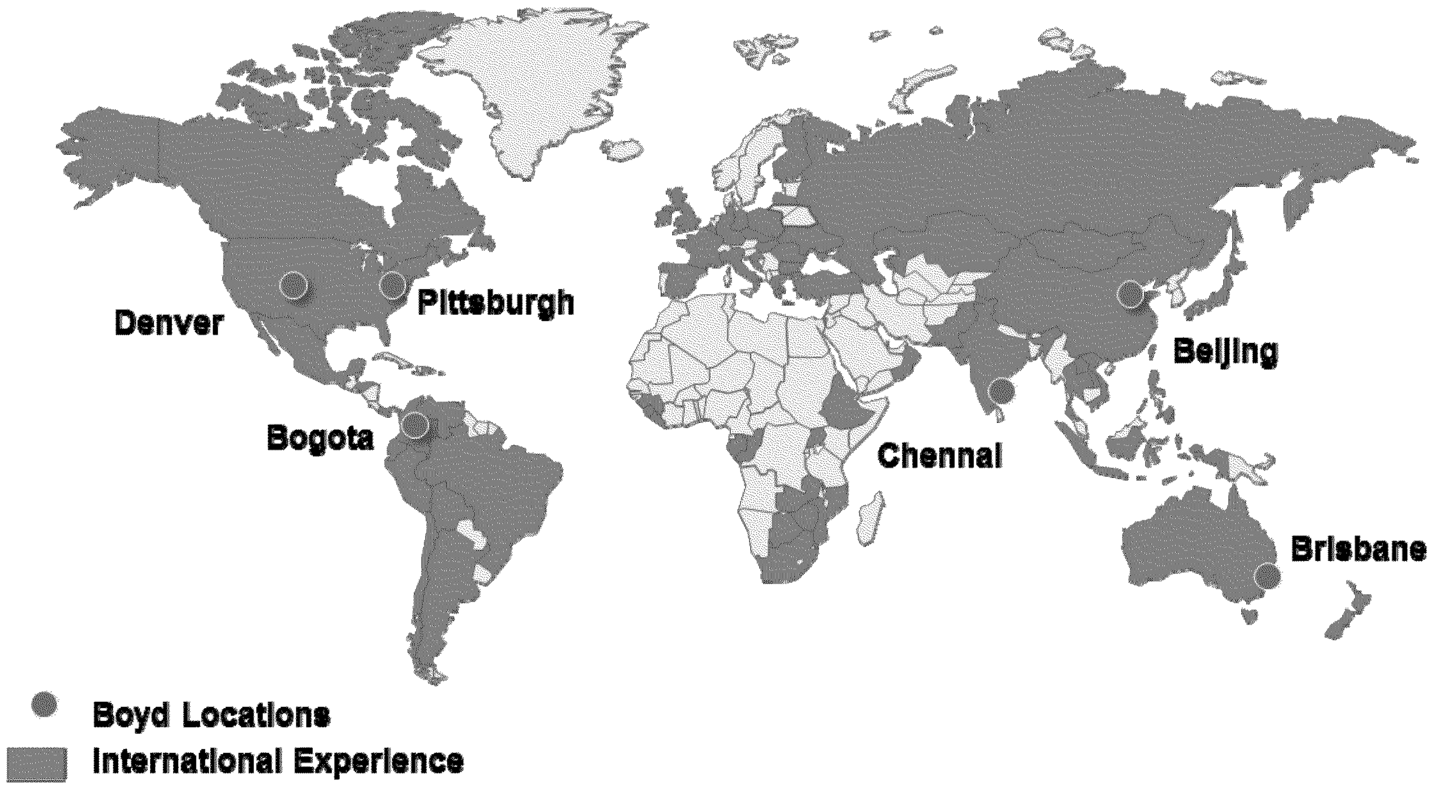
Experience in Over 50 Countries



The Role of Cement Creek

A Right Bank Tributary to the Upper Animas River

Primary Source of Pollutants in Upper Animas River

- Acid water
- Dissolved heavy metals
- High turbidity

Cement Creek

How Did it Get This Way?

Intense sulfide mineralization coming into contact with oxygenated water.

- Mineralization from Silverton Caldera (ancient volcano)
- Involves surface and underground hydrologic system
- Network of faults due to tectonic stresses from collapsing caldera provides conduits for oxygenated water to enter the groundwater system and percolated downward to escape to through seeps and springs, and through mine portals.

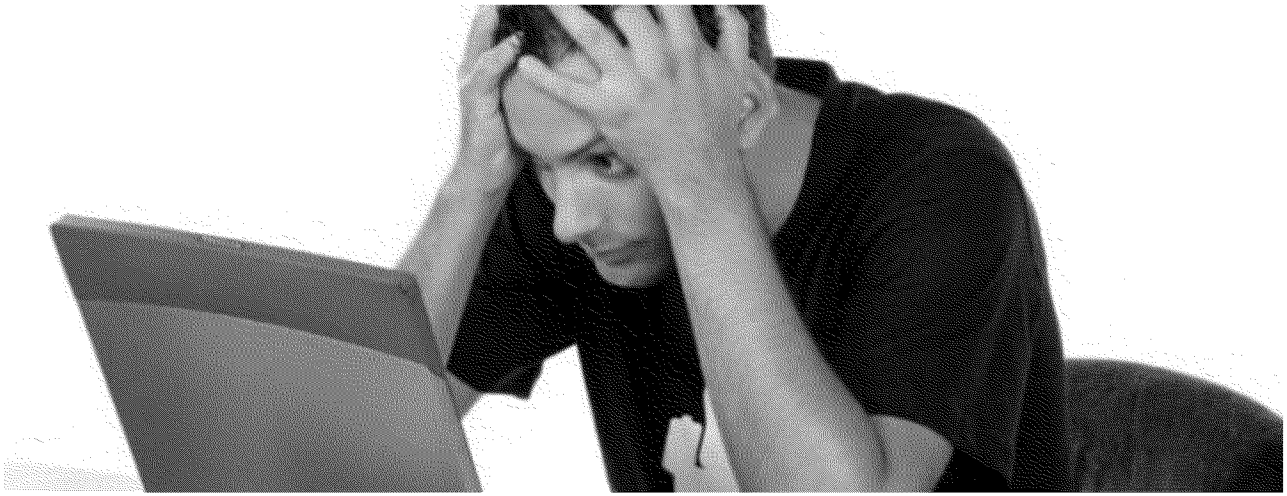
Cement Creek

Is Historic Mining Responsible?

Partially, but it has always existed to some degree.

- Evidence collected by the USGS confirms that it has been a problem to some degree for at least 4,500 years.
- Historic mining activities have certainly exacerbated the problem
  - Introduced more oxygenated water to the underground hydrologic regime
  - Dramatically increased available reactive sulfide surfaces
  - Adits have provided additional drainage to the creek

Hurdles to Plan Development



- Cost (Initial and on-going)
- Technology hurdles
- Perpetual active treatment
- Stakeholder divisions
- Who is Responsible
- Public/private issues

Strategy for Success

Must

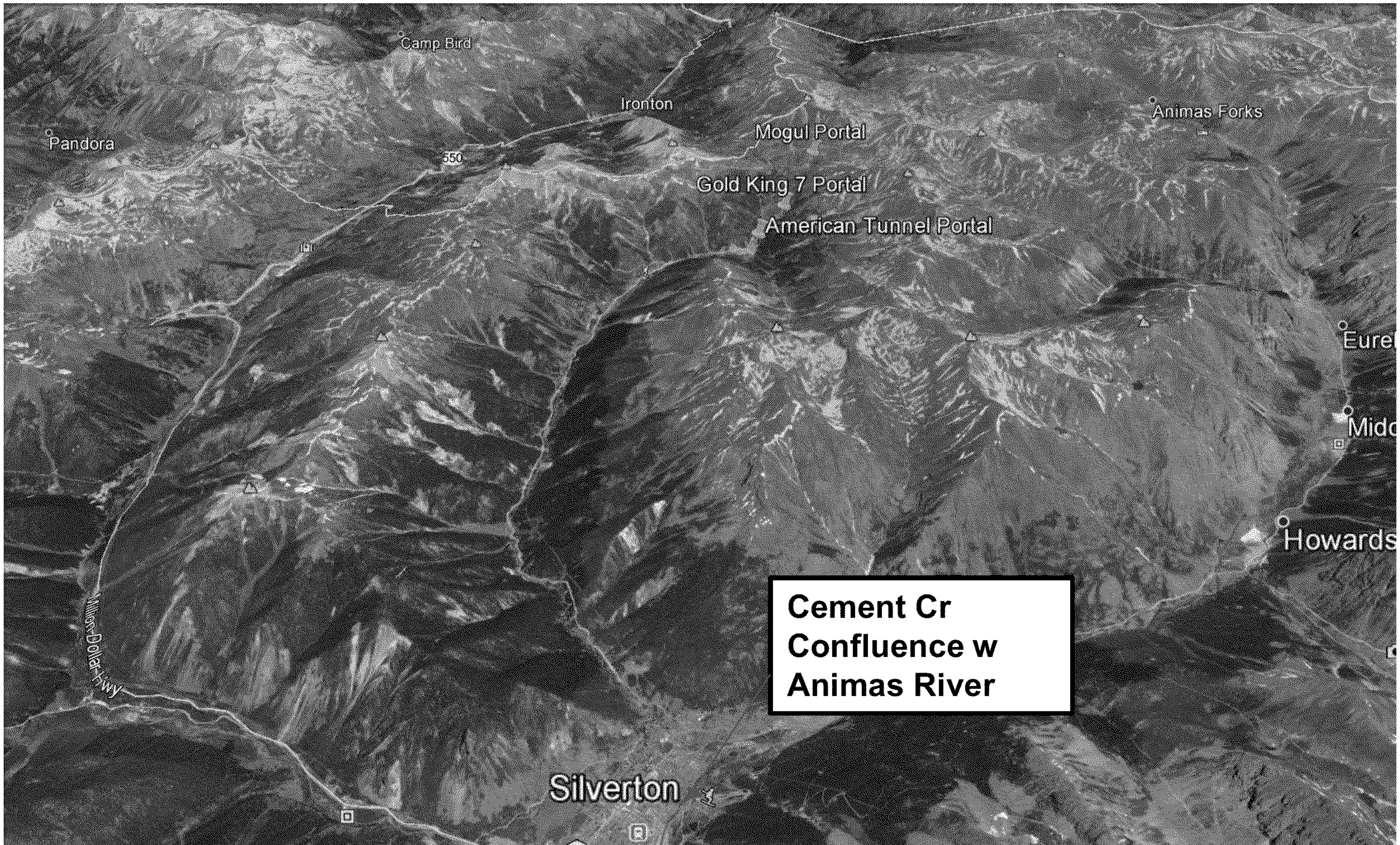
- Rely on Proven Technology
- Be Cost-Effective and Affordable
- Begin With Active Transitioning to Passive Treatment
- Be Drainage-Wide (Cement Cr) in Scope
- Not Impair Private Interests
- Be Collaborative
- Involve Cost Sharing

The BOYD Concept

- Collect Cement Cr Drainage Just Above Animas R. Confluence for Temporary Active Treatment
- Maximize Use of Gravity to Save $$$
- Limestone as Principal Treatment Agent (well proven)
- Use Locally Available Limestone to Save $$$
- Build In Redundancy to Avoid Upsets (spills)
- "Inoculate" Reactive Sulfide Surfaces Underground to Make Stable
- Once Stable, Transition to Open Flow Passive Treatment

Upper Cement Cr. Drainage

Overview Cement Cr. Drainage



Cement Cr Joining Animas R.

During Gold King Spill

Photo by Ray Dileo/Silverton Standard

Locally Available Limestone

For Period of Active Treatment

USGS Has Mapped Limestone Deposit Within 2 miles of Silverton

- Ouray Limestone 12 – 15 meters thick
- Leadville Limestone 60 meters thick
- Units are in direct contact one above the other

LS Units Located Southwest of Silverton at Basal Elevation of 9,450ft – Silverton at Approximately 8,980ft

Cost Difference for LS

For Period of Active Treatment

Nearest Commercial Limestone

- Salida, CO – 248 mi – fob Silverton cost $45 - $60/ton
- Delta, CO – 107 mi – fob Silverton cost $40 - $55/ton
  (costs similar due to Red Mtn Pass and smaller loads)

Local Limestone Production prelim estimate - $10/ton

- Direct production cost including capital amortization
- No trucking required

No Firm Estimate Yet for Annual Tonnage, but likely to be in the range of 20,000 – 25,000 tons per year minimum

Order of Magnitude Savings - $700k - $1 million/yr

Local LS Production Plan

Small Scale Underground Quarry

- Shallow decline from surface
- Portal below from valley floor
- Install crushing equipment u/g
- Ore pass from LS horizon to portal elevation

No weather impacts on u/g quarry

Active Water Treatment Plant

Underground Installation

- **Locate u/g plant beneath LS deposit**
- **Portal driven from valley floor Southwest of Silverton**
- **Install diversion and overflow near mouth of Cement Creek** (divert base flow [6cfs/3,000gpm] to treatment plant w flood overflow directly to Animas River)
- **Pipe flow for treatment to u/g treatment facility by gravity** (1.7 miles / 94 ft drop)

Cheaper to pipe water downhill than haul gravel up

Animas River Water Quality Solutions

John T. Boyd Company

Conceptual Site Plan

Diversion, Pipeline, and U/G Treatment Plant

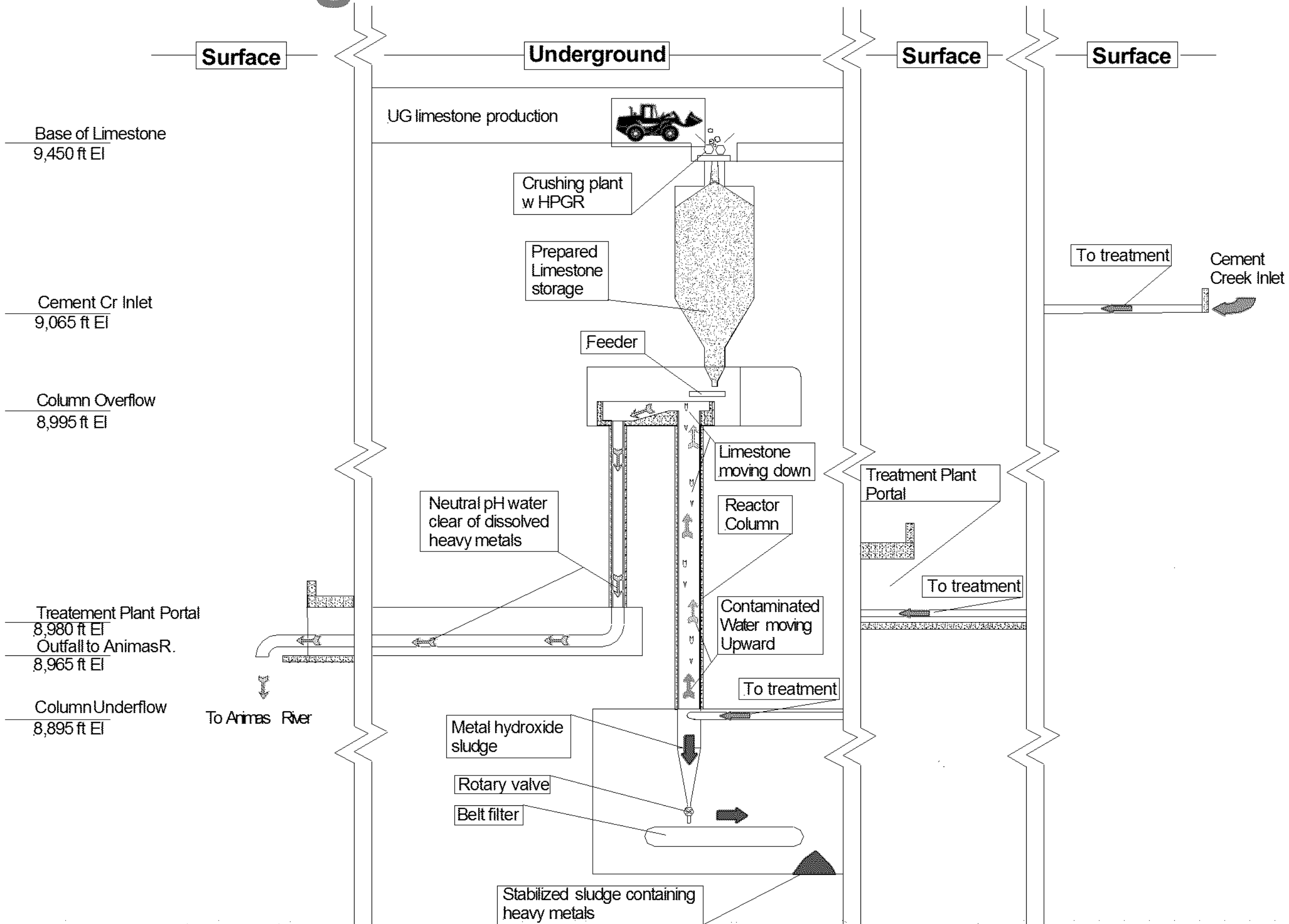
Prepared for Animas River Key Influencers – October 2015

Active Treatment Plant

Design Technology

- Very tall counter-current reactor column(s)
- Contaminated water flows by gravity from bottom of column to decant over the top
- Prepared LS is fed from the top to slowly settle through the water column raising pH and collecting metal hydroxides as the particles travel downward
- Metal hydroxide sludge settles to a collection cone at the bottom
- Sludge feeds to a belt filter through a rotary valve

Active Treatment Plant
General Arrangement



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Active Treatment Plant

Discussion

- Use HPGR to achieve uniform particle size (+/- 2mm) and to create micro-fractures in LS particles
- May need limited NaOH for fine pH adjustment to achieve levels necessary for Zn precipitation
- Will include redundant reactor circuit to provide back-up for upsets and maintenance
- May need second stage reactor in series for polishing
- Alternative polishing may include Zeolyte filtration

Active Treatment Plant

Sludge Handling

- Settled sludge concentrated in collector cone to be metered through rotary valve
- Sludge to be dewatered utilizing a belt filter
- Sludge "cake" discharged from belt filter to be collected for permanent storage
- Filtrate water to be re-injected into reactor feed
- Sludge to stored on site

Active Treatment Plant

Permanent Sludge Storage Alternatives

Storage in excavated limestone caverns

- Would require elevation to cavern level (vertical conveyor)
- Most secure as buffered environment
- No additional stabilization required

Storage in surface cell near portal

- Would likely require portland cement stabilization
- Less secure
- Surface footprint required
- Comparative costs need to be studied

Active Treatment Plant

Major Advantages to BOYD Plan

- Treatment of entire base flow of Cement Creek (+/- 6 cfs or 3,000 gpm)
  - Captures all flows from any source in drainage
  - Provides for flood overflow when surface dilution water is greatest, thus maintaining water quality in Animas River
- Harnesses gravity to avoid pumping costs (capex, opex, and maintenance)
- Locally available Limestone (cost savings estimate at $700k to $1million/yr)
- Gravity delivery of Limestone to treatment plant, i.e., no trucking

Active Treatment Plant

Major Advantages to BOYD Plan – (cont.)

- Use of rock mass (u/g plant) to preclude need for building envelope and elimination of structural elements for plant
- Ability to practicably utilize very long reactor columns to achieve optimum reaction times
- Relatively little mechanical equipment to be purchased and maintained
- No weather related issues with underground system
- High efficacy, cost-effective treatment to permit treatment of entire base flow from Cement Creek

Phase I Active Treatment Plant

BOYD Plan

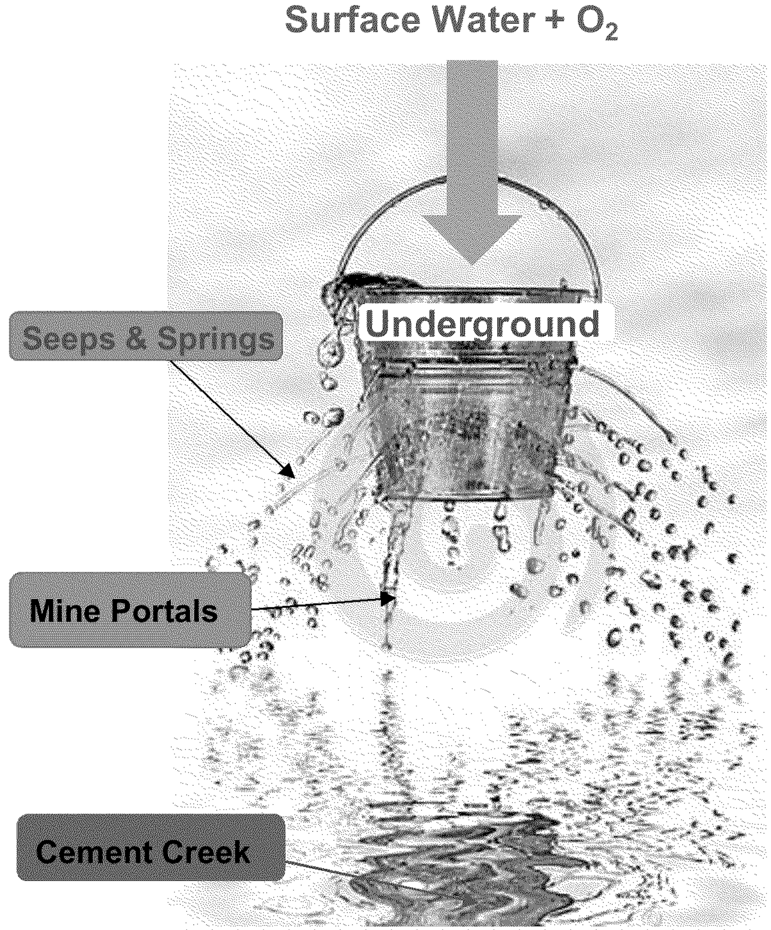
Prepared for Animas River Key Influencers – October 2015

Phase II Permanent Reduction of AMD

KEY ISSUES

Attempts to seal portals have not been successful to date

- Plan was to reduce oxygen level in static water to prevent sulfide reaction
- Problem has been the u/g hydro regime has too many leaks
- Result is continuous turnover w fresh oxygen rich water from surface continuing to react and leak producing AMD and draining into Cement Creek



Phase II "Inoculation"

Alternative to Leaking Bucket

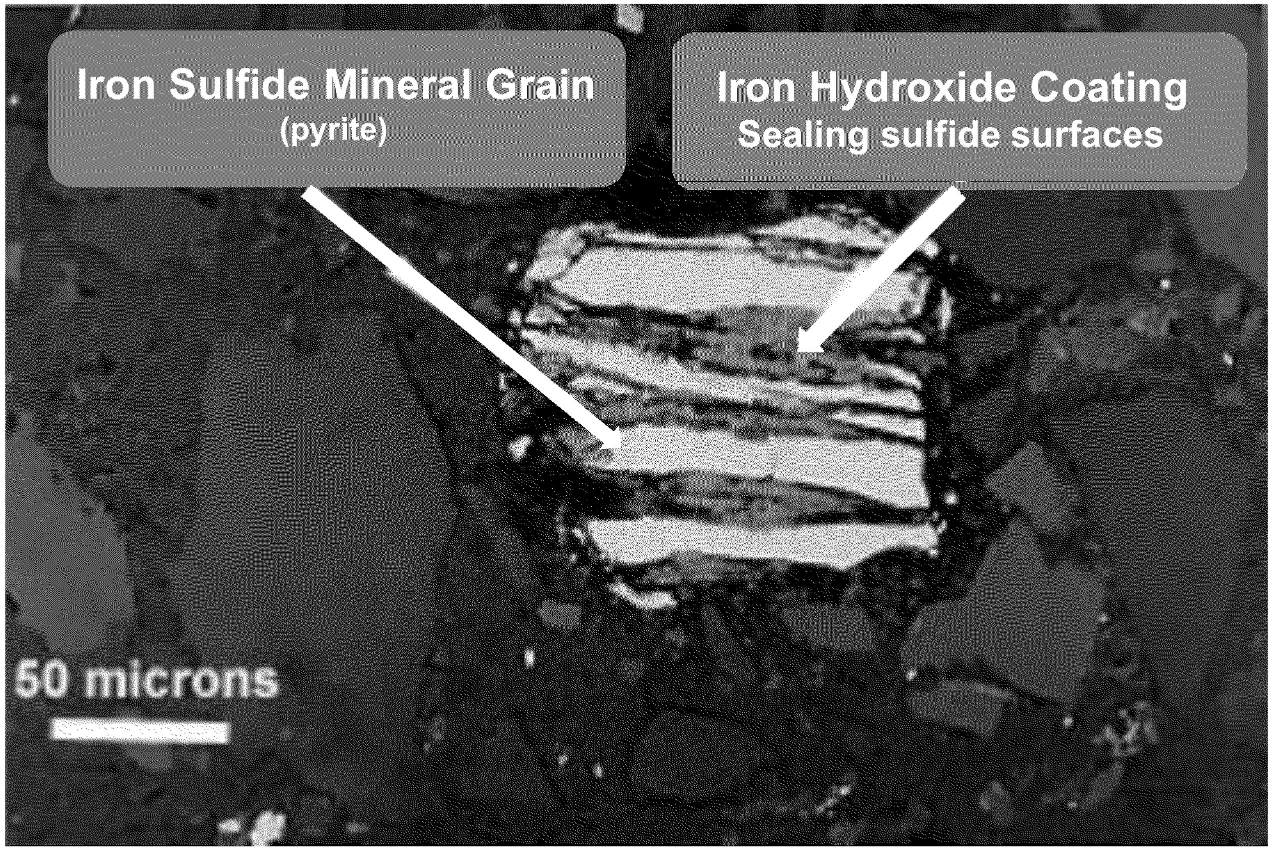
With Active Treatment System On Entire Cement Creek Drainage in Place ...

- Construct temporary seals (bulkheads) in all know mine portals
  - Install large diameter dump valves through bulkheads
  - Install pressure gages to determine hydrostatic head
- Close valves and build water to maximum equilibrium head
- Identify, map, and monitor seeps and springs (flow and quality)
- Drill multiple injection wells into underground openings distributed over hydrologic regime (maybe a couple of dozen?)
- Inject massive doses of buffering agent (NaOH) plus compressed air into wells to oxidize mineral surfaces and render non-reactive
- Alternatively, or perhaps in combination with, inject bio-oxidants for the same purpose

Phase II "Inoculation"

How it Works

Note iron hydroxide coating surface of sulfide surfaces rendering them unavailable for further acid generating potential



Phase II "Inoculation"

Why it Will Work

- Water in entire hydro regime below the static water level will be rendered strongly basic in the presence of oxygen (NaOH and compressed air injection) to oxidize surfaces
- Inevitable leakage will bring treated water in contact with surfaces in fractures including micro-cracks
- Hydro system may require multiple cycles to provide thorough inoculation potentially involving
  - Differentially raising and lowering impounded water behind various bulkheads
  - Cycling the entire hydrologic system
- Sulfides existing above static head equilibrium will not be exposed to inoculation, but should eventually seal over as well

Phase III Transition to Passive

Gradual and With Active System On-Line

- Water behind each bulkhead would be drawn down in sequence beginning with uppermost elevation to maintain uniform static head
  - Continuous monitoring to confirm efficacy
  - Re-inoculation if water quality not meeting requirements
  - Flow rate gradually increasing to max capacity of active treatment plant
- Cover remaining acid generating dumps and divert surface flows if any
- Install crushed Limestone drains from portals and major seeps
- Install crushed Limestone in the lower portion of Cement Creek channel
- **Shutdown active treatment plant**

JOB DONE

Passive Treatment On-going

Well Not Quite … Must Monitor and Maintain Fail-Safes

- On-going monitoring
  - At each point source (quality and flow)
  - Cement Creek contribution (quality and flow)
- Immediately close valve on any bulkhead experiencing an upset
- Re-inoculate as necessary, e.g. a fall of ground exposing fresh sulfide surfaces
- Maintain active treatment plant in ready-state to deal with upsets
- As hydrologic system stabilizes monitoring frequency can be reduced to annual.

The Way Forward

Must Involve Agencies and Government at Federal, State & Local Levels Working Together with Stakeholders

- Agree on logical steps to move forward
- Identify key roles
  - Planning
  - Execution
- Find funding source(s)
  - Feasibility
  - Active treatment period
  - On-going passive system monitoring

The Way Forward

Project Phase – Feasibility Study

- Definitive data collection
- Component trade-off studies
- Proof of key concepts (testing)
- Final scoping/project definition
  - Phase I –Active treatment
  - Phase II – Inoculation
  - Phase III – Transition to passive system
- Capital Cost estimating (capex)
- Operating Cost estimating (opex)
- Project Schedule

Order of Magnitude Cost Estimate - $2.0 – 3.0 million

The Way Forward

Project Phase – Active Plant Construction

- Develop and equip u/g limestone production facility
- Construct u/g water treatment plant
  - Portal and u/g excavation
  - Install mechanical equipment
- Install pipeline from Cement Creek to facility
- Construct Cement Creek diversion structure

Capex Cost Guestimate - $12.0 – 15.0 million
Opex Cost Guestimate - $1.0 – 2.0 million/yr

The Way Forward

Project Phase – Inoculation of u/g system

- ☐ Construct bulkheads w valves and instrumentation
- ☐ Drill and equip injection wells
- ☐ Inject buffering/bio-oxidation solution (plus compressed air)
- ☐ Staged drawdown of hydrostatic head
- ☐ Monitoring

Capex Cost Guestimate - $5.0 – 7.0 million
Opex Cost Guestimate - $1.5 – 2.5 million/yr*

* Includes on-going active plant operation

The Way Forward

Order of Magnitude Costs

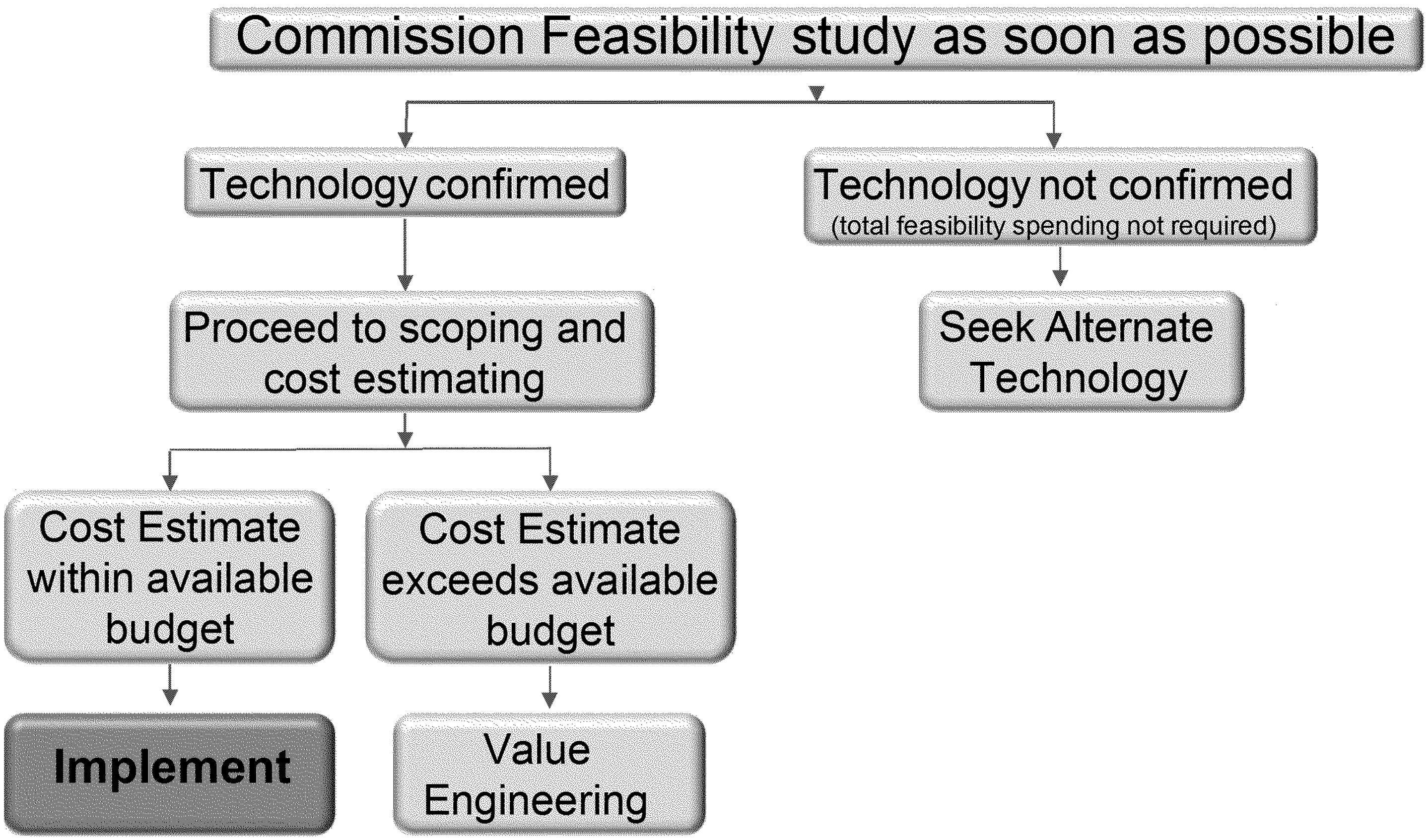
Total Capex $19 - $25 million

Total Opex $8.5 – $14.5 million
(assumes 1 yr active plant only plus 5yrs to complete inoculation)

Grand Total $27.5 – $39.5 million To Permanently Restore Water Quality In the Upper Animas River Spread over Approximately 7 years time

The Way Forward

Key Recommendation and Decision Points



Conclusion
At Last!

- BOYD believes it has developed a logical, workable, and cost-effective action plan to permanently meet target water quality standards in the upper Animas River

- Naturally, we would like to be involved

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Thank You

Greg Sparks, P.E.
MD - Metals

John T. Boyd Company

4000 Town Center Boulevard
Suite 300
Canonsburg, PA 15317
United States
724.873.4400 Ph

www.jtboyd.com

John T. Boyd Company
mining and geological consultants
Pittsburgh - Denver - Australia – China – Colombia - India